Corrib Gas Pipeline

Oral hearing

Brief of Evidence

Groundborne Noise and Vibration

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Acoustics - Noise - Vibration

1. NAME, QUALIFICATIONS AND ROLE IN PROJECT

1.1 My name is Rupert Thornely-Taylor.

1.2 I am a Fellow of, and was a founder member of, the Institute of Acoustics, a Member of the Institute of Noise Control Engineering of the USA and a Member of the International Institute of Acoustics and Vibration. I have specialised exclusively in the subjects of noise, vibration and acoustics for more than 46 years. I have been an independent consultant in these subjects for the past forty two years, and head the practice known as Rupert Taylor F.I.O.A.

1.3 I am President of the Association of Noise Consultants and a Director of the International Institute of Acoustics and Vibration. I was for ten years a member of the British Government's Noise Advisory Council chaired by the Secretary of State for the Environment, and was chairman and deputy chairman of two of its working groups; I was a member of the Scott Committee, which drafted the basis of the noise section of the UK Control of Pollution Act 1974. I am an Examiner for the Institute of Acoustics Diploma.

1.4 My practice has, over the past 20 years, developed a numerical modelling programme for predicting vibration generation and transmission in structures, soils and fluids known as *FINDWAVE®*, a Finite-Difference-Time-Domain package which has been widely used around the world for the prediction of vibration from underground sources.

1.5 I am the author of the Pelican book NOISE, and editor or co-author of many other books.

1.6 I have over twenty years' experience in assessing groundborne noise and vibration from tunnelling, dating from the tunnel drive of the extension to Bank of the Docklands Light Railway in London in the late1980s, and have been involved in the construction of the tunnels of the Jubilee Line Extension in London, Copenhagen Metro, Malmö

Citytunnel, and the planning of tunnels for Dublin Metro North. Crossrail in London, Västlänken in Sweden, the Circle Line in Singapore, and I have studied groundborne noise and vibration from the Channel Tunnel and the Channel Tunnel Rail Link in the UK, the Dublin Port Tunnel, the tunnel for the Brighton and Hove Wastewater Treatment Works in the UK, among many tunnels around the world.

2. GENERAL INTRODUCTION

2.1 My evidence relates to the subject of noise and vibration from the construction of the tunnel for the onshore pipeline. The tunnelling work will generate vibration which will propagate through the ground and through water. There are potential impacts from the vibration, in the form of ground vibration and underwater noise which may be detectable by a range of avian and aquatic species, and which require consideration with regard to groundborne noise or vibration at buildings near to the shore of Sruwaddacon Bay.

2.2 The first part of my evidence sets out the method used for the assessment of the significance of vibration and groundborne noise effects on human beings and buildings. The assessment of the significance of the effects of vibration and underwater noise on avian and aquatic species is presented in the evidence of Ian Wilson and Jenny Neff. The assessment of the effects of vibration on ground stability are addressed in the evidence of Turlough Johnston.

2.3 The second part of my evidence describes the method used for predicting likely levels of vibration, groundborne noise and underwater noise.

2.4 The third part of my evidence assesses the results of the prediction work against the assessment criteria for human beings and buildings.

3 ASSESSMENT CRITERIA

3.1 As explained, assessment criteria for effects on avian and aquatic species are addressed in the evidence of Jenny Neff and Ian Wilson, and those for ground stability in the evidence of Turlough Johnston.

3.2 With regard to the effects on human beings and buildings, there are no applicable Irish standards. In such circumstances, it is appropriate to following best international practice, having regard to the approach adopted by other comparable projects in Ireland. International vibration standards have been issued in Europe by the British Standards Institution (BSI), the International Organization for Standardization (ISO) and the Deutsches Institut für Normung (DIN).

3.3 The most recent guidance on the human response to vibration from demolition and construction activities has been issued in BS 5228-2:2009 based on thresholds expressed in terms of "peak particle velocity" or ppv, which is the maximum speed reached at any time by a point on a vibrating surface. In the case of a tunnel boring machine, the ppv value is typically about 3 times greater than the "root-mean-square" or r.m.s. value, which is the conventional measure used for averaging an oscillating quantity such as vibration. While r.m.s. values may be expressed as a frequency spectrum, ppv is a maximum of the total vibration across the spectrum. The ratio of ppv to overall r.m.s. is known as the crest factor.

3.4 The following table from the Standard is particularly relevant:

Table 1: Human Response to Vibration from Construction and Demolition Activities

Vibration Level PPV (mm/s)	Effect
0.14	Vibration might be just perceptible in the most sensitive situations for most vibration frequencies associated with construction. At lower frequencies, people are less sensitive to vibration.
0.3	Vibration might be just perceptible in residential environments.
1.0	It is likely that vibration of this level in residential environments will cause complaint, but can be tolerated if prior warning and explanation has been given to residents.
10	Vibration is likely to be intolerable for any more than a very brief exposure to this level.

Source: BS 5228-2

3.5 This guidance is in fact the most stringent of current standards, and assuming a crest factor of 3, a ppv of 0.14mm/s or 140µm/s equates to a root-mean-square (r.m.s.) value of 47 µm/s and 0.3mm/s or 300µm/s equates to an r.m.s. value of 100 µm/s. When r.m.s. values are analysed into frequency bands, individual band levels are lower than the overall total.

3.6 Vibration within the sea bed causes underwater sound, which is expressed using the decibel scale. However, the underwater decibel scale is not the same as the decibel scale used for sound in air for two reasons. One is that a different reference base to the scale is used, (1 µPa for sound in water compared with 20 µPa for sound in air –which gives a difference of 26dB simply due to a shift in the reference level), another is that for the same amount of energy, sound pressure is higher in a denser and much less compressible medium such as water than it is in a light and compressible medium such as air.

3.7 Particle acceleration in water is relevant to consideration of effects of underwater sound on fish, and there is a direct relationship between underwater sound pressure and particle acceleration.

3.8 Groundborne noise refers to noise perceived by the sense of hearing that differs from noise in general, insofar as it arrives in the space where it is heard as a result of propagation as vibration (at acoustic frequencies) through the ground or through a structure. For example, vibrating room surfaces cause airborne sound to be radiated and the effect is sometimes referred to as re-radiated noise.

3.9 The generally adopted practice in the case of groundborne noise from tunnelling or underground railways is to use the maximum noise level index, $L_{Amax,S}$, to characterise the effects. For dwellings that are not currently affected by groundborne noise, the threshold of significance is typically taken as 35 dB $L_{Amax,S}$.

4 GROUNDBORNE NOISE AND VIBRATION FROM TUNNELLING

4.1 The tunnelling operation will be a continuous 24-hour process and is described in the evidence of Tim Jaguttis. Vibration from tunnelling is caused when the TBM's cutting shield rotates whilst being under a constant pressure from hydraulic cylinders that push the TBM forward.

4.2 The excavation process will generate forces within the sands, gravel and rock that may propagate as groundborne vibration. These vibrations will travel through the ground as various different waveforms dependent on the nature of the geology surrounding the TBM. The other activities within the main tunnelling cycle are unlikely to generate significant vibration within the ground. The TBM will be supported by a temporary construction railway to transport materials, such as tunnel lining segments, and personnel to the face. This may cause very transient vibrations to be generated, particularly when segment wagons pass over rail joints. However, levels of vibration will generally be no higher than those expected from the TBM and would only occur for seconds at any particular location.

4.3 There is a potential for groundborne vibration from the tunnel excavation by the TBM to be detected within the sands forming the sea bed within Sruwaddacon Bay. This vibration will also be transmitted to water within the Bay and will generate sound within the water body. The nature and extent of the sound levels will vary with the amount of water in the Bay and the location of the TBM.

4.4 Groundborne vibration has the potential to be transmitted to residential and other buildings near to the shore as “feelable” vibration and groundborne noise re-radiated from the ground via building structures to cause audible sound.

4.5 In considering all of the above potential effects it should be considered that:

- The TBM will move at, on average, 11m per day and hence effects will be temporary and transient; and

- The excavation process which has the potential to generate vibration typically lasts for approximately 15 - 20 minutes in each hour.

4.6 The effects of groundborne noise and vibration from tunnelling that I have assessed are based on the results of the *FINDWAVE*® modelling which is reported in detail in Appendix H3 of the EIS.

4.7 This model is a numerical method for computing the propagation of waves in elastic media, i.e. soils, rock, structures and fluids (including air and water) The excitation is provided from a random array of impulses applied to the tunnel face. The model predicts the dynamic behaviour of the medium surrounding the tunnel face.

4.8 Output from the model consists of time series of the velocity of transverse and longitudinal sections through the model, which are subjected to frequency transformation and expressed as 1/3 octave band spectra.

4.9 The model was calibrated by reference to measured data from the tunnel drive of the Dublin Port Tunnel for which the northbound tunnel drive began in June 2002 and the southbound drive was completed in August 2004. The tunnel was bored through a mixture of limestone bedrock and glacial till overburden (boulder clay). During the course of the tunnel drive of the Dublin Port Tunnel, the project carried out extensive monitoring of the groundborne noise and vibration that occurred at specific locations along the scheme.

4.10 The models were created based on the drawings included in Appendix H3. Cross sections through the models were created for the locations shown in Slide 1.

4.11 Separate model runs were undertaken for high and low water. The high water level was as in Slide 1. The low water level exposes the sand layer completely except in the region of the river channel.

4.12 The model output has a frequency bandwidth of 1Hz to 100Hz. The vibration caused by a TBM outside this range is not of significant amplitude.

4.13 The model is deterministic, and for a given set of parameters will give an exact solution subject only to the very small errors inherent in the finite-difference method. Consequently the accuracy of the results is dependent on the correctness of the input parameters. For studies involving soil and rock, the exact properties of the propagating medium cannot be known precisely, and it is necessary to test the model result to discover the effects of a range of uncertainties in the input parameters. The model has been applied to many circumstances where it has been possible in due course to measure the actual vibration predicted by the model, and an uncertainty allowance of +3dB (+40% in amplitude terms) where the source characteristics are known applied. To take into account uncertainty in the source characteristics a total allowance +5dB (+80%) is allowed..

5 ASSESSMENT FINDINGS

5.1 Slide 2 shows the envelope of the distance at which TBM vibration is predicted by the results of the modelling work to reach 0.1mm/sec This is one third of the figure of 0.3mm/second which according to BS 5228 “might be just perceptible in residential environments” ppv.

5.2 The closest residential properties to the tunnelling are located near to the narrowest part of the mouth of Sruwaddacon Bay on the road (L1202) between Pollatomish and Glengad The house referred to as BQ07 (shown in Appendix A of the Corrib Onshore Pipeline EIS) is approximately 234m from the tunnel. This house and nearby properties are likely to experience the highest levels of vibration from tunnelling. Taking account of the vibration throughout the 10Hz to

100Hz range, the predicted PPV at the house is estimated to be in the range 0.01 to 0.02 mm/s. Comparing this value with Table 1 indicates that this is a level that is considerably below the threshold of human perception for vibration, even allowing for an 80% uncertainty margin, indicating there will be no impact from the operation of the tunnel boring machine. Since the vibration from the operation of the temporary construction railway will be no greater than that of the TBM, there will also be no impact from the temporary railway even when considered cumulatively with vibration from the TBM.

5.3 Such a low level of vibration is also well below the thresholds where even minimal cosmetic damage can be caused to buildings.

5.4 Based on a perception threshold of 0.14mm/s ppv, there is no house on land either side of the bay where vibration will perceived by humans.

5.5 There would be no significant vibration effect even when the vibration from the TBM and temporary railway are considered in combination with vibration from construction vehicles on the highway.

5.6 The corresponding predicted groundborne noise level is 9 dB $L_{Amax,S}$. It can be seen that such a level is well below the significance criterion of 35dB $L_{Amax,S}$ even after allowing a 5dB uncertainty margin and would be inaudible within any residential property, again indicating no impact.

6 CONCLUSION

6.1 The conclusion is that neither vibration nor groundborne noise will be perceptible by any resident in the vicinity of the proposed tunnelling works, and will therefore have no effect on human beings or buildings.

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Groundbourne Noise and Vibration

By Rupert Thornely-Taylor

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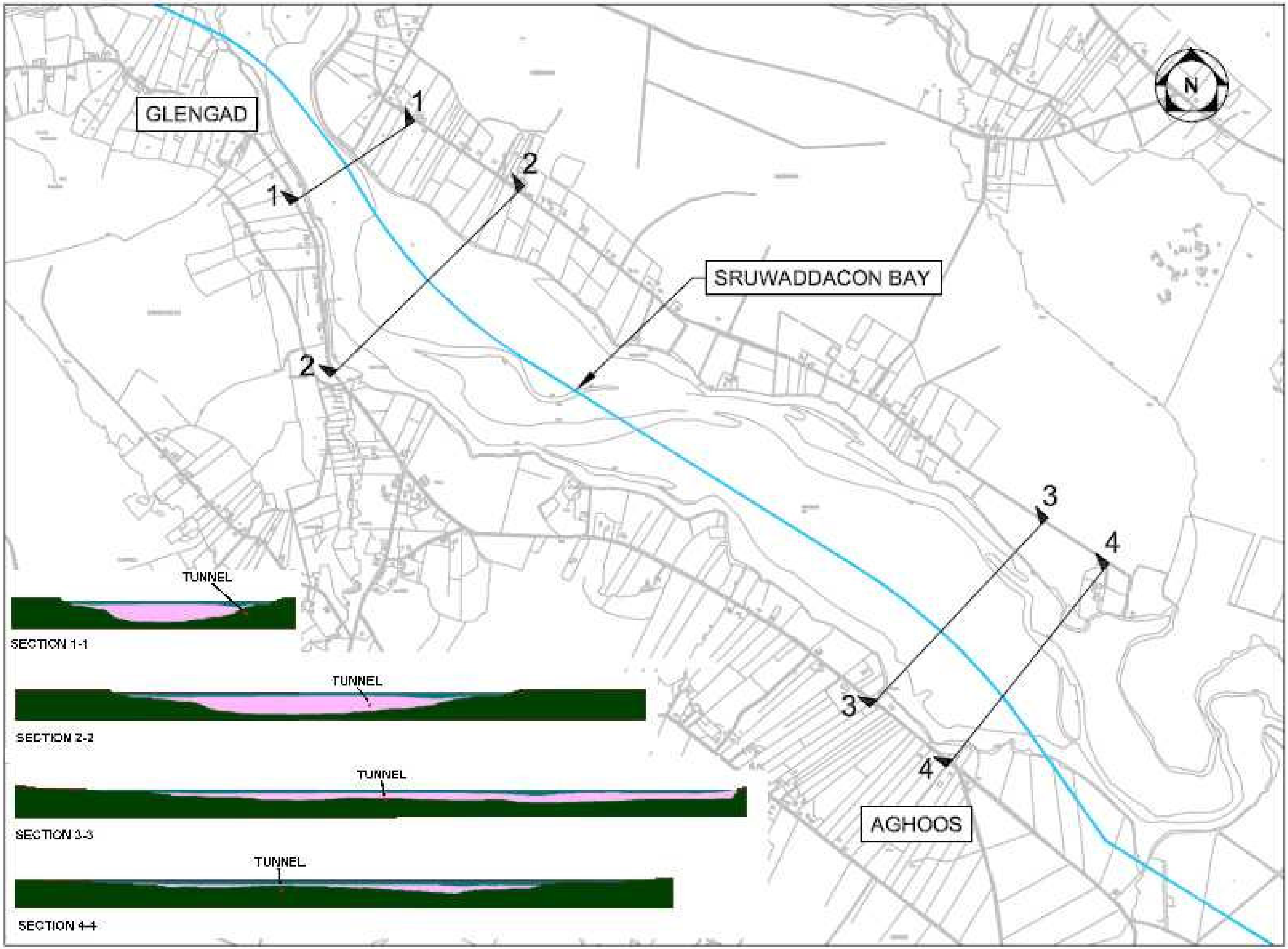
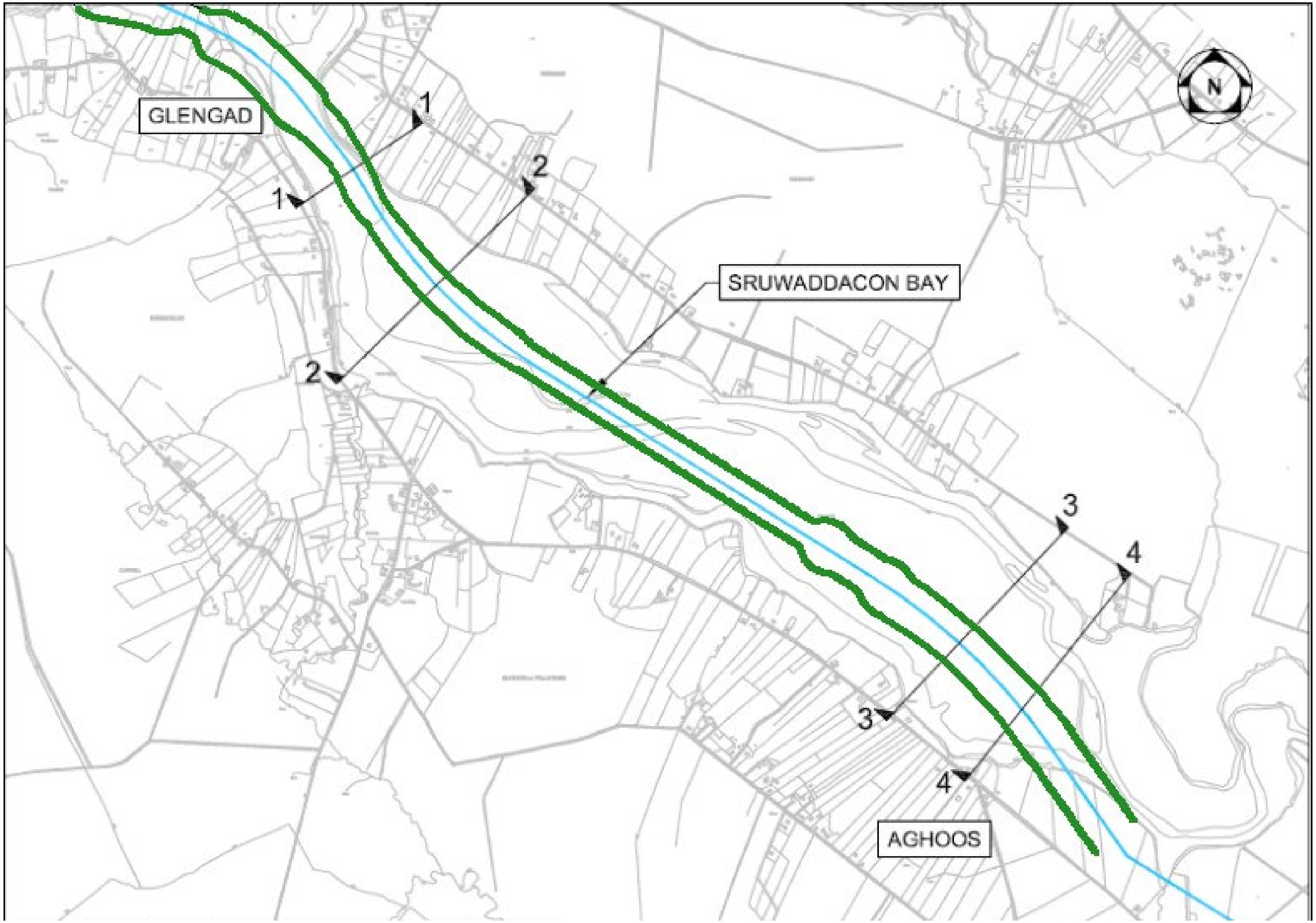


Sections used in Findwave modelling

1



Contour of limit of human perceptibility of TBM vibration